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Patternator™: A new Method of Improving Deposit Uniformity in a Crosswind

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Abstract. *Aircraft spraying in a crosswind usually exhibit deposit patterns that differ significantly from those obtained when flying into a headwind. A crosswind increases deposits under the upwind wing resulting in over-application and decreases deposits under the downwind wing resulting in under-application. The resulting swaths are less uniform with reduced effective swath widths. To correct the pattern, it is suggested that certain upwind nozzles contributing to the over-application should be shut off, and the same number of downwind nozzles should be turned on. Therefore, the boom configuration would change with each pass (turn) of the aircraft. The PATTERNATOR is a mechanical device that automatically changes the boom configuration with each aircraft pass to maintain uniform patterns in both a left- and right- crosswind. Patternation trials conducted in cooperation with the USDA-ARS Aerial Application Research Unit in College Station, Texas, demonstrated that the system can be retrofitted to existing aircraft and boom configurations that increase both swath width and uniformity could be identified. The best performing configurations on an Ag Husky were those where three upwind nozzles were shut off and three new nozzles were interspersed in the middle of the downwind boom.*

Keywords. Pattern uniformity, Patternation, Swath width, Aircraft calibration

Introduction

Examination of several years of data collected from calibration and patternation tests of agricultural aircraft, patterned under crosswind conditions, have indicated significant pattern distortion caused as a result of the crosswind. Several attempts to decrease the pattern distortion by simply changing the position of existing nozzles on the boom (shortening or lengthening the boom) proved futile. To better address this issue, a relatively simple pneumatic/electrical/mechanical device was developed. This device can significantly improve the deposition pattern of a fixed wing aircraft when spraying in a crosswind.

Crosswind Pattern Distortion

An agricultural aircraft typically produces an effective swath width that is wider than the actual aircraft (Figure 1, top). This is a result of outward movement of air caused by the higher pressure under the wings. A crosswind from the left would reduce this outward airflow from under the left wind significantly decreasing spray travel and deposition in the upwind direction. It follows that a significant portion of the deposition that would otherwise be deposited out past the wing tip would cause a 'high spot' somewhere in the deposition pattern (Figure 1, bottom)..

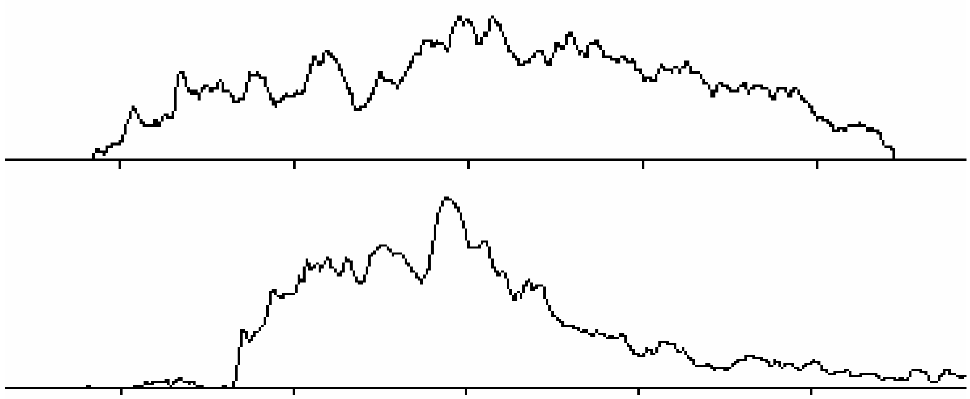

Figure 1: String deposit pattern of Ag Husky in a headwind (top) and in a crosswind from the left of the picture (bottom).

The Patternator™

Shutting off those nozzles that contribute to the pattern distortion and adding additional nozzles to "fill-in" where needed, swath uniformity can be improved. The Patternator™ controls the output of selected nozzles by modifying their check valve so air pressure can be applied to the top of the diaphragm, keeping the nozzle shut off even when the boom is pressurized. The booms are configured depending on the requirements of that aircraft, and the Patternator™ unit changes configuration whenever the aircraft experiences a 180º turn. In this way, the upwind and downwind booms are always optimized, without pilot input (Figure 2).

Methods

Trials were conducted in cooperation with the USDA-ARS Aerial Application Research Unit, College Station, TX in October 2005. An Ag-Husky (N2182J) equipped 22 CP03Poly (CP Products Company, Inc., Tempe, Arizona), 0.125" orifice at 30º, operating at 40 psi, flew 15 feet above ground at an airspeed of 110 mph. The aircraft was retrofitted with Patternator™ hardware, and seven configurations were evaluated (Table 1). On the day of the trial (October 26), air temperature averaged 24ºC, 23% RH, and a crosswind of 5.8 mph. All treatments were conducted on the same day, replicated three times in each flight direction.

Figure 2: Ag Husky with three upwind nozzles shut off (left side) and three nozzles added to downwind end of boom (treatment 3).

Table 1: Treatment List for Patternation Trials at College Station, October 26, 2005

Treatment	Upwind Boom	Downwind Boom
1	All on	All on
2	Outside 3 nozzles off	All on
3	Outside 3 nozzles off	Lengthen boom by 3 nozzles
4	Every second outside 3 nozzles off	All on
5	Every second outside 3 nozzles off	Intersperse 3 new nozzles along existing boom
6	Outside 3 nozzles off	Intersperse 3 new nozzles along existing boom
7	Outside 6 nozzles off	Intersperse 6 new nozzles along existing boom

Pattern uniformity was determined using string patternator (WRK of Arkansas, Lonoke, AR), as well as with water sensitive paper spaced 5' apart and analyzed using DropletScan (WRK of Arkansas). The swath width was calculated from the Droplet Scan data by solving for a total over-application of 15% of the deposited amount. Pattern uniformity was determined by calculating the amount of over-application at a 50' swath width. Analysis of variance was conducted using a randomized complete block design, and when significant effect occurred, means were separated using LSD technique at p=0.05 (SAS Institute Inc., Cary, NC).

Results

Treatments significantly affected excess deposit calculated at a 50' swath width (ANOVA p=0.0094). Treatment 6 had the lowest overall excess (11.5% of total deposit), significantly lower than the reference treatment (1) at 22% of total (Table 2).

Treatments also significantly affected swath width at which excess deposit was 15% (ANOVA p=0.0073). Again, treatment 6 provided the widest swath, at 54.3 ft significantly wider than treatment 1 (45 ft).

Treatment 5 performed nearly as well as treatment 6, but although it had less excess deposit and wider swath widths than the reference treatment, differences were not significant.

The remaining treatments were equivalent or worse than treatment 1. This suggests that configurations must be chosen carefully.

Table 2 Spray swath excess deposit at 50' width and swath width at which 15% excess deposit was obtained for seven treatments (mean of 6 runs).

Treatment	Excess deposit at 50' swath width (% of total)	Swath Width at 15% Excess Deposit (feet)
1	22.0 bcd[1]	45.0 bc
2	27.4 bcd	44.4 bc
3	38.3 abc	41.8 bc
4	40.3 ab	39.7 c
5	18.0 cd	47.2 ab
6	11.5 d	54.3 a
7	53.7 a	40.0 bc

[1] Numbers in a column followed by the same letter are not significantly different (LSD, p=0.05)

Although there was significant variation in the results based on changing wind conditions, it appears that configurations in which three upwind nozzles were turned off and three downwind nozzles were interspersed in the center of the downwind boom provided the biggest improvement. Treatments where no new downwind nozzles were added, or where they were added to extend boom length, did not perform well, as did those where too many (6) nozzles were reconfigured. An example of the deposit pattern from Treatment 5 with a crosswind of 8 mph (from the left) is shown in Figure 3.

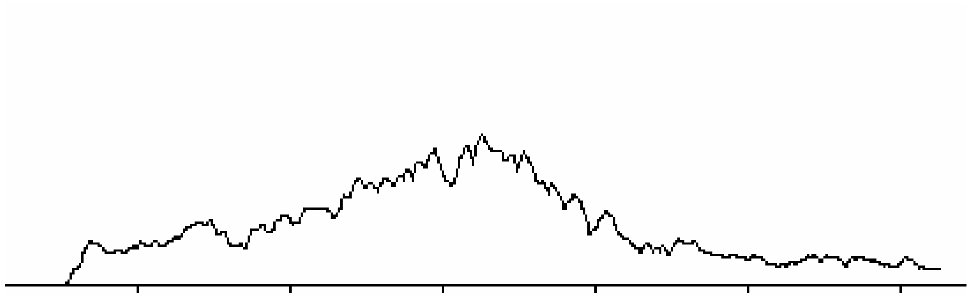

Figure 3. Spray swath pattern with a crosswind from left of image in which three upwind nozzles were shut off and three new nozzles were interspersed on the downwind boom (Treatment 5).

Conclusions

- Installed hardware allowed boom configuration to change automatically as plane turned.
- When upwind nozzles were turned off and new downwind nozzles were interspersed, crosswind patterns improved significantly.
- When downwind nozzles were not added or were added at the end of the boom, patterns were not improved.
- Further work is required to optimize pattern for other aircraft, atomizers, and under a wider range of crosswind conditions.

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